HUMBER RIVER PLUME TRACKING

Great Lakes Section

Water Resources Branch

Ontario Ministry of the Environment

August 1985

HUMBER RIVER PLUME TRACKING

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for the

Great Lakes Section

Water Resources Branch

Ontario Ministry of the Environment

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Humber River Plume Tracking

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8. ABSTRACT

A deflector dyke at the Humber River mouth was constructed in June 1984 to deflect the river flows away from the Sunnyside Beaches. This study utilized Lagrangian techniques, i.e. tracking a marked volume of river water. The Lagrangian measurements are considered more representative of the physical process than the Eulerian measurements (flow past a fixed point) since the former technique follows the water volume as it travels, thereby identifying the actual path of the river plume. Tracking studies showed that in no instances did Humber River water enter behind the breakwater through the landfill gap at the eastern end of the breakwater.

Sail drogues at depth and surface drogues, in conjunction with dye released at the river mouth, illustrated that the river water can intrude through the gaps of the concrete breakwater structures (parallel to the shoreline) during southerly winds.

Information presented in this report is the result of short duration surveys and should not be assumed to reflect predominant flow pattern in the area. However, the results obtained can be incorporated in a mathematical model to illustrate the flow regime behind the breakwater and to assess design modifications for the existing breakwater structures.

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HUMBER RIVER PLUME TRACKING

SUMMARY

A deflector dyke at the Humber River mouth was constructed in June 1984 to deflect the river flows away from the Sunnyside Beaches. This study utilized Lagrangian techniques, i.e. tracking a marked volume of river water. The Lagrangian measurements are considered more representative of the physical process than the Eulerian measurements (flow past a fixed point) since the former technique follows the water volume as it travels, thereby identifying the actual path of the river plume. Tracking studies showed that in no instances did Humber River water enter behind the breakwater through the landfill gap at the eastern end of the breakwater.

Sail drogues at depth and surface drogues, in conjunction with dye released at the river mouth, illustrated that the river water can intrude through the gaps of the concrete breakwater structures (parallel to the shoreline) during southerly winds.

A cluster of four sail drogues and dye released under the Humber River bridge were used to determine the dispersion coefficients (a measure of spread of a waste field). These coefficients can be used as input to predictive models to assess the waste dilutions and their impact.

A line of four drogues were also released under the Humber River bridge to determine the behaviour of different water parcels across the river width. Observations showed the presence of oscillatory motions, as well as movements across the river due to the effects of lake processes.

Several single sail drogues were released at the centre of the the breakwater openings and then tracked. The data collected were used to compute exchange of water through the gaps and the residence times behind the breakwater. The net mass flow ranged from 0.27 to 4.88 m^3/s and the residence times varied from 5 to 33 h.

Information presented in this report is the result of short duration studies and should not reflect predominant flow patterns in the area. However, the results obtained can be incorporated in a mathematical model to illustrate the flow regime behind the breakwater and to carry out scenerios under different climatological conditions. Based on the scenarios, a management scheme could be derived to alter the breakwater configurations in order to reduce or eliminate any adverse impacts from the Humber River flows on the western beaches.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

HUMBER RIVER PLUME TRACKING
1984

BACKGROUND

A deflector dyke was constructed between the western breakwater and the shore to prevent the Humber River water from entering behind the western breakwater. It was found that the degraded water quality in the Humber River was affecting the recreational use of the water behind the breakwater. This study was undertaken to trace the Humber River water in the nearshore regions of Lake Ontario with the deflector dyke in place. Water movement dispersion in the nearshore region of the Great Lakes is variable and one cannot expect to determine general statistical relationships from a few days of tracking. We can, however, show some characteristics of the movement of the Humber River water into Lake Ontario because we are tracking Humber River water using Lagrangian techniques, e.g., following marked volumes of river water.

OUTLINE OF STUDY

The Humber River plume was followed using several different techniques and the water exchange through the gaps in the western breakwater was also measured.

Time-Sequential Drogue Release

On two different days, the river plume was tracked by sequentially releasing water sail drogues set at a depth to measure the river plume at 40-minute intervals at the outlet of the Humber River. Figure 1 shows the sail and surface drogues used. These drogues have been extensively used to trace discharges and water movements in the coastal zones in conjunction with dye releases and have been found to trace the movement well. The sail drogues were then individually tracked using Loran-C for about six hours. Up to

seven drogues were released over a period of 2.5 hours. This study traces the path of the 2.5 hours of river water over a period of 5 to 6 hours (see Figures 2 and 3).

Drogue Cluster Release

The river water was also tracked by releasing a cluster of four water sail drogues and dye patches. The path of the individual drogue was determined using Loran-C positioning. At any time after release, the centroid of the four drogues represents the mean path of the cluster and the spread of the drogues is a measure of the dispersion. The dispersion was also determined by measuring concentration profiles in a dye patch in two orthogonal directions.

Line of Drogues Across River

The study was also to determine if portions of the river water moved towards the breakwaters. To study this, a line of water sail drogues was positioned across the river cross-section at the river outlet and released simultaneously. These drogues were tracked individually with Loran-C for six hours. A second and third line of drogues were released at 40-minute intervals and individually tracked in a similar manner. This study was repeated twice.

Water Exchange Through Breakwater Gaps

The water exchange between the water behind the breakwater and the lake at the western end of the breakwater was measured. To do this, water sail drogues were simultaneously released in the four gaps at the western end of the breakwater and were tracked for a short period of time to measure the velocity in the gaps. The drogues were then repositioned into the centre of the gaps and the process repeated. This study was carried out for 5 and 6 hours on two different days. From the study, water movement in and out of the gaps over a period of 5 to 6 hours was determined.

DISCUSSION OF RESULTS

Time-Sequential Drogue Release

The two days of tracking on August 1 and 7 of sequentially-released drogues are presented in Figures 2 and 3. The drogues were released in Humber River water near the outlet. The prevailing wind speed and direction at the various times during the tracking are also shown in Figures 2 and 3. The winds were generally southerly during the tracking studies on August 1 and 7. On August 1, all the drogues moved towards the East, offshore of the breakwater. Three of the drogues did not travel as far and remained within 275 m of the Humber River. On August 7, all five drogues released ended up going through the gaps in the western breakwater and remained behind the breakwater. These trackings show that Humber River water can end up behind the western breakwater during southerly winds. We do not, however, have a measure of the magnitude of the phenomena or the impact of the Humber River on the water quality behind the breakwater.

Drogue Cluster Release

The tracking of a release of a cluster of water sail drogues at the bridge was carried out on October 4 for southwest winds. The results are presented in Figure 4. The drogues were confined to the Humber River outlet area for 4 hours and the study was terminated. This study shows the oscillatory motions in the confines of the river outlet, however, the magnitude and frequency of these oscillations could not be quantified in this limited study.

Line of Drogues Across River

The results for the time-sequential release of 3 drogues (Figure 5) in a line across the river cross-section at the Lakeshore Boulevard Bridge are shown in Figures 6 to 8 for releases at 1150, 1250 and 1330 h respectively on September 11 for southeast wind conditions. For the 1150 h release, the westerly most drogue remained near the western bank of the river while the other two drogues went out into the lake and then into the embayment at Humber Bay Park. For the release at 1250 h, all the drogues went towards the embayment at Humber Bay Park. For the 1330 h release, the two westerly

drogues moved into the embayment at Humber Bay Park and the easterly most drogue moved out into the lake. These trackings show that different portions of the river cross-section can behave differently but in no instance did the easterly portion of the river cross-section move behind the Western breakwater.

The same procedure was repeated on October 9, only this time 4 drogues were released, one from the centre section and three from the east side. The releases were carried out at 1040, 1115 and 1150 h as shown in Figures 9 to 11.

The 1040 release (Figure 9) had three drogues travelling out to the breakwater. The fourth drogue, closest to the river bank, experienced some direction reversals and eventually stagnated at the river bank. Two drogues, upon passing the breakwater, experienced direction reversals. All drogue paths crossed other paths.

The 1115 release (Figure 10) was similar to the 1040 release. Two drogues reached the breakwater, while one beached. The other drogues moved across the river to the west bank then returned to the East bank.

The last release (Figure 11) of 1150 hours had the three eastern drogues move along the eastern bank. The fourth drogue moved down the centreline of the river and reversed direction once before moving toward the east bank. At no time did any drogue enter the gap at the breakwater.

This study shows that water movement in the river outlet is not confined to stream tubes which follow the well-defined geometry of the river banks. River water does move across the river cross-section or channel. However, in no instance was river water tracked through the gap between the breakwater and the shore at the western end of the breakwater. The fill between the breakwater and the shore is effectively preventing the entry of river water at this gap.

Water Exchange Through Breakwater Gaps

The water movement through the gaps in the western breakwater was measured on August 14 and 27. On both days, southwesterly winds existed. Details on the gaps and the numbering system are presented in Figure 12. The movements in the gaps were measured with water sail drogues which were concurrently released in the centre of the gaps then tracked for about 15 minutes. The drogues were then repositioned in the centre of the gaps and the process repeated for 5 to 6 hours. The measured movements for August 14 for Gaps 1, 2, 3 and 4 are presented in Figures 13 to 16, respectively. Similar data for August 27 are presented in Figures 17 to 20.

On August 14, the water movement in all the gaps was shoreward. On August 27, there was a net shoreward movement through Gaps 1 and 4 and lakeward through Gaps 2 and 3. The net water mass through the gaps for August 14 and 27 for the study have been summarized in Table 1. From Table 1, we can estimate the residence time behind the western breakwater for the two days of study. By estimating the volume of water enclosed behind the breakwater centered on each gap, assuming that water levels do not change, it is possible to crudely estimate the residence times. The volume estimates are based on marine chart data and some spot depth measurements. No estimate is possible for Gap 4 because the volume of water behind the breakwater cannot be defined with the rubble fill in the gaps to the East. Based on the measurements on August 14th and 27th, the residence times behind Gaps 1, 2 and 3 are 5 to 21, 6 to 16 and 13 to 33 hours, respectively.

Dye Dispersion in River

A dye release was made at the bridge on October 4 at 1050 h. The spreading of the dye is shown in Figure 21 at each measuring time. The length of the major and minor axis of the dye patch were measured to estimate the dispersion. The dispersion estimates and data are shown on Table 2.

CONCLUSIONS

The tracking studies showed that in no instances did Humber River water enter behind the breakwater through the gap at the Western end of the breakwater. The fill between the breakwater and the shore at the western end appears to be effective in deflecting the Humber River Water offshore of the breakwater. The Humber River water did enter behind the breakwater through the existing gaps in the breakwater. Velocity measurements in these gaps over a period of 6 hours on August 14th and 27th showed that there is a significant net flow from the lake towards the shore through the three westerly breakwater gaps. We also found that water movement across the river occurred frequently due to lake processes. In other words, the river water did not follow well-defined stream tubes related to the cross-section of the river. Across the river, mixing was occurring near the outlet.

Table 1

EXCHANGE RATE DATA

DATE	LOCATION	TOWARD SHORE "-" VELOCITY (cm/s)	TIME (min)	MASS FLOW (m^3)	TOWARD LAKE "+" VELOCITY (cm/s)	TIME (min)	MASS FLOW (m^3)	FOR SAMPLING PERIOD NET MASS FLOW (m^3)	NET MASS FLOW RATE (m^3/s)
Aug.14	Gap I	1.4	177	4480	1.8	79	2530	- 1945	0.127
		3.0	232	12570	1.8	79	2530	- 10030	0.538
	Gap II	2.5	300	22680	0.8	5.6	135	- 22540	1.23
		3.2	338	31840	1.6	9.4	443	- 31400	1.51
	Gap III	3.0	293	34420	2.0	67.5	5450	- 28970	1.34
	Gap IV	2.2	308	67590	1.1	43	4830	- 62760	2.98
Aug.27	Gap I	3.0	152	7980	1.1	156	3130	- 4850	0.263
	Gap II	2.3	86	5800	2.5	219	16130	+ 10325	0.563
	Gap III	2.0	146	11340	4.1	118	19390	+ 8060	0.508
	Gap IV	3.0	315	92310				- 92310	4.88

Calculations based on widths and depths as follows:

	Depth (m)	Width (m)	Area (m^2)
Gap I	2.7	11.0	29.7
II	4.0	12.4	49.6
III	5.3	12.5	66.25
IV	5.5	30.0	165.0

(Widths from Harbour Commission's Engineering Dept.)

Table 2

DYE RELEASE AT BRIDGE - OCTOBER 4, 1984

(Dye Released at 1050 H)

Time	Centroid Data Distance (m)	Speed m/s	Cloud Data Length (m) Major	Minor	X (m) Major	Minor	Standard Deviation (m^2) Combined	Dispersion m^2/s
1113	76.49	0.054	93	50.8	57.7	20.1	170.8	0.0599
1201	22.85	0.0079	116.8	45.3	55.9	22.5	589.2	0.0684
1323	54.62	0.0111	290	59.6	116.11	36.3	2905.7	0.1577

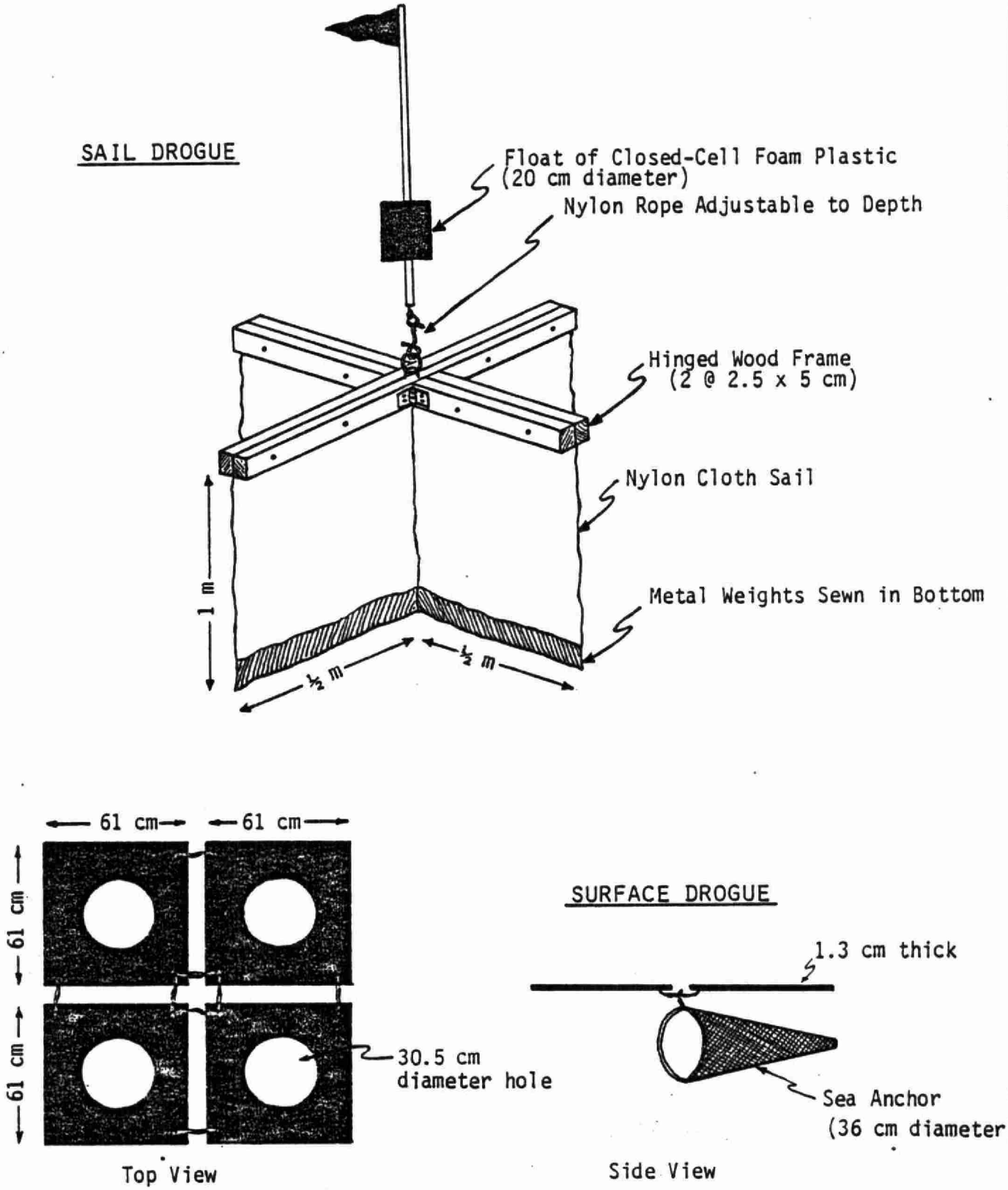

SAIL DROGUE
Float of Closed-Cell Foam Plastic
(20 cm diameter)
Nylon Rope Adjustable to Depth
Hinged Wood Frame
(2 @ 2.5 x 5 cm)
Nylon Cloth Sail
Metal Weights Sewn in Bottom
1 m
½ m
½ m
61 cm
61 cm
61 cm
61 cm
30.5 cm
diameter hole
Top View
SURFACE DROGUE
1.3 cm thick
Sea Anchor
(36 cm diameter
Side View

Figure 1

Date: August 1, 1984
Sunny & warm 22°C
1 ft swell
Wind @ 5 knots from SW @ 1100
Release Point: 433751.3 @ 5' depth
792814.9

Sail Drogues:

1 First released @ 1050 - changed direction @ 1439

2 Second released @ 1135 - changed direction @ 1443

3 Third released @ 1223 - changed direction @ 1514

WIND VECTOR
9 e.g. wind to North @ 9 km/h

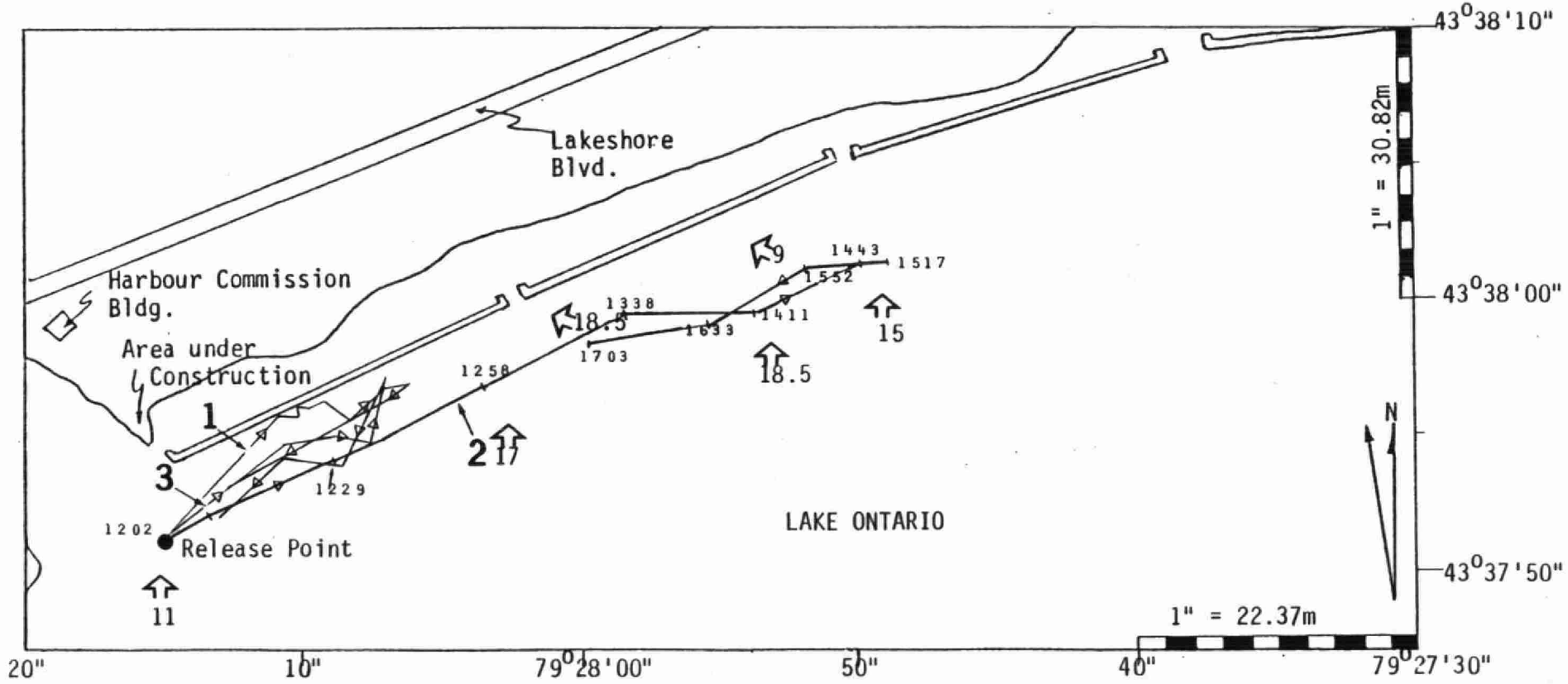


FIGURE 2(a)

Date: August 1, 1984 - continued

Drogues:

1 Surface Drogue released @ 1130

2 Surface Drogue released @ 1215

3 Surface Drogue released @ 1305

4 Sail Drogue released @ 1305 - changed direction @ 1513

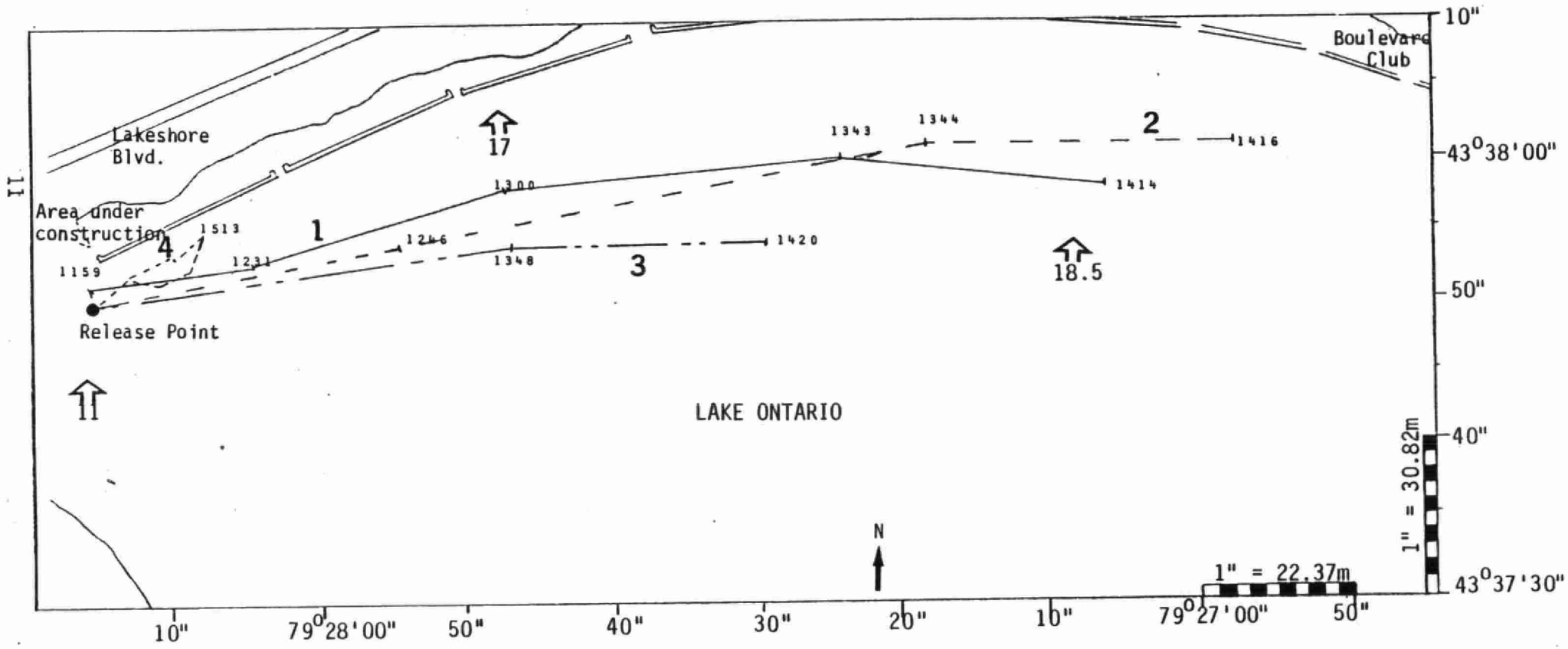


Figure 2(b)

Date: August 7, 1984
Clear, sunny
Light wind
Release Point 433749.9
792812.4

Sail Drogues:

1 First released @ 1044

2 Second released @ 1113

\+ Dye released @ 1105

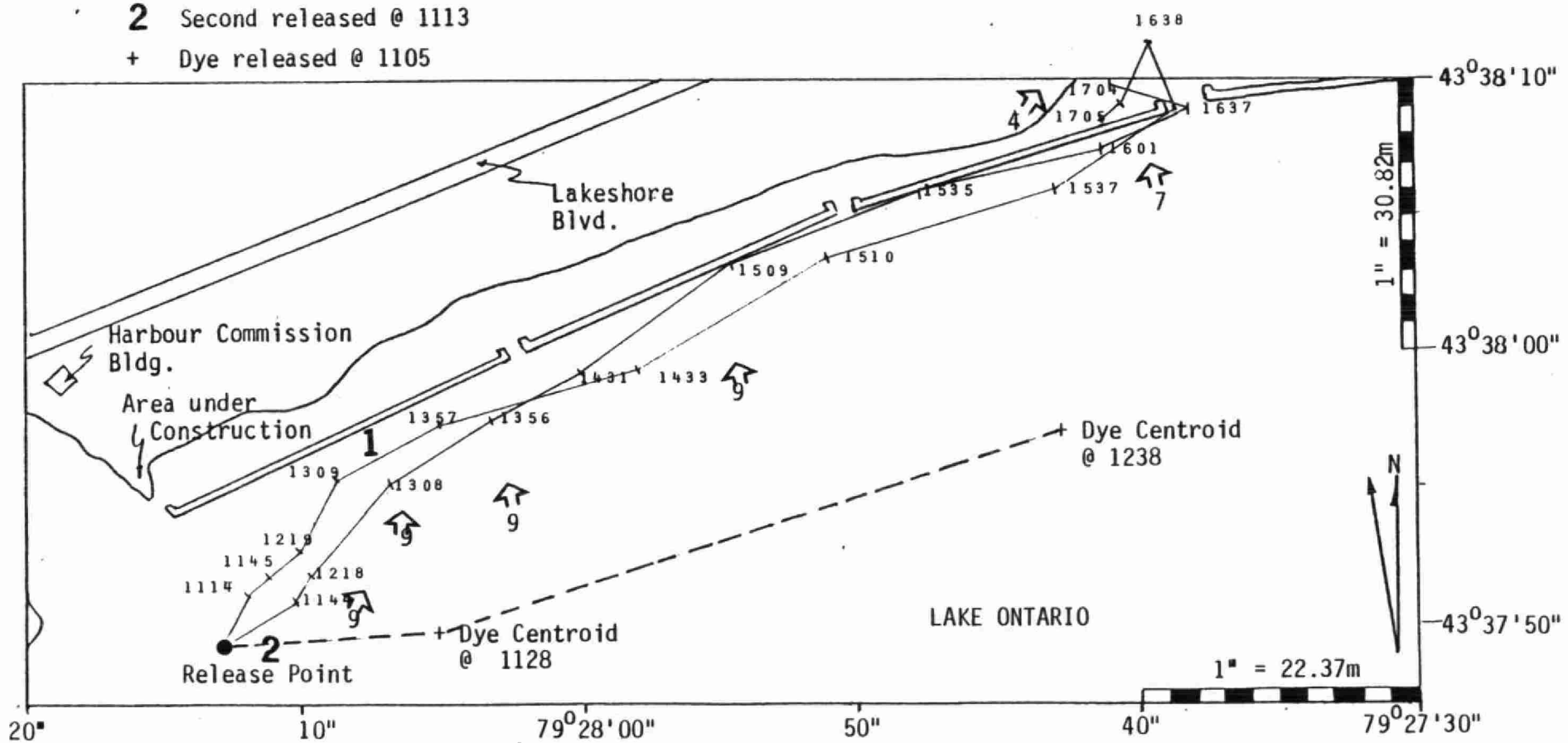


FIGURE 3(a)

Sail Drogues:

1 First released @ 1143

2 Second released @ 1213

3 Third released @ 1305

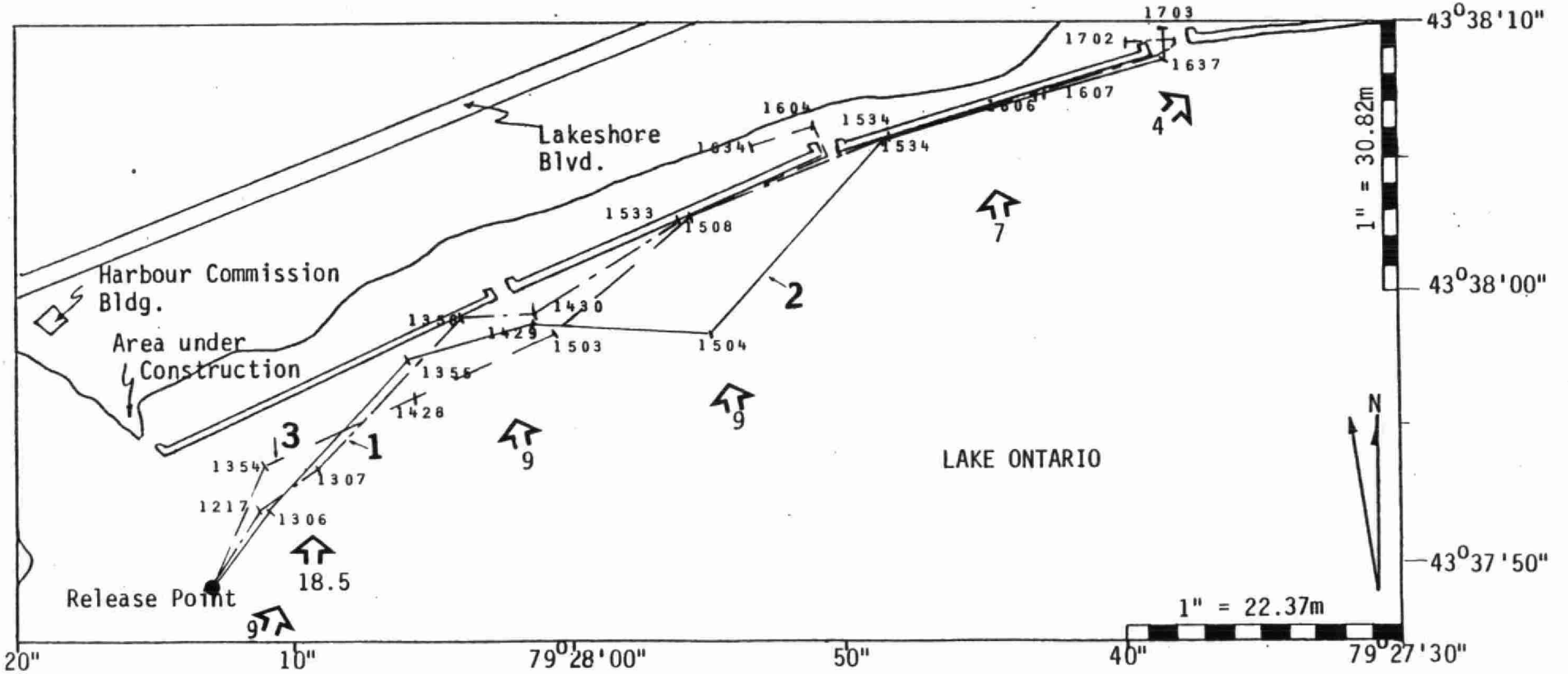
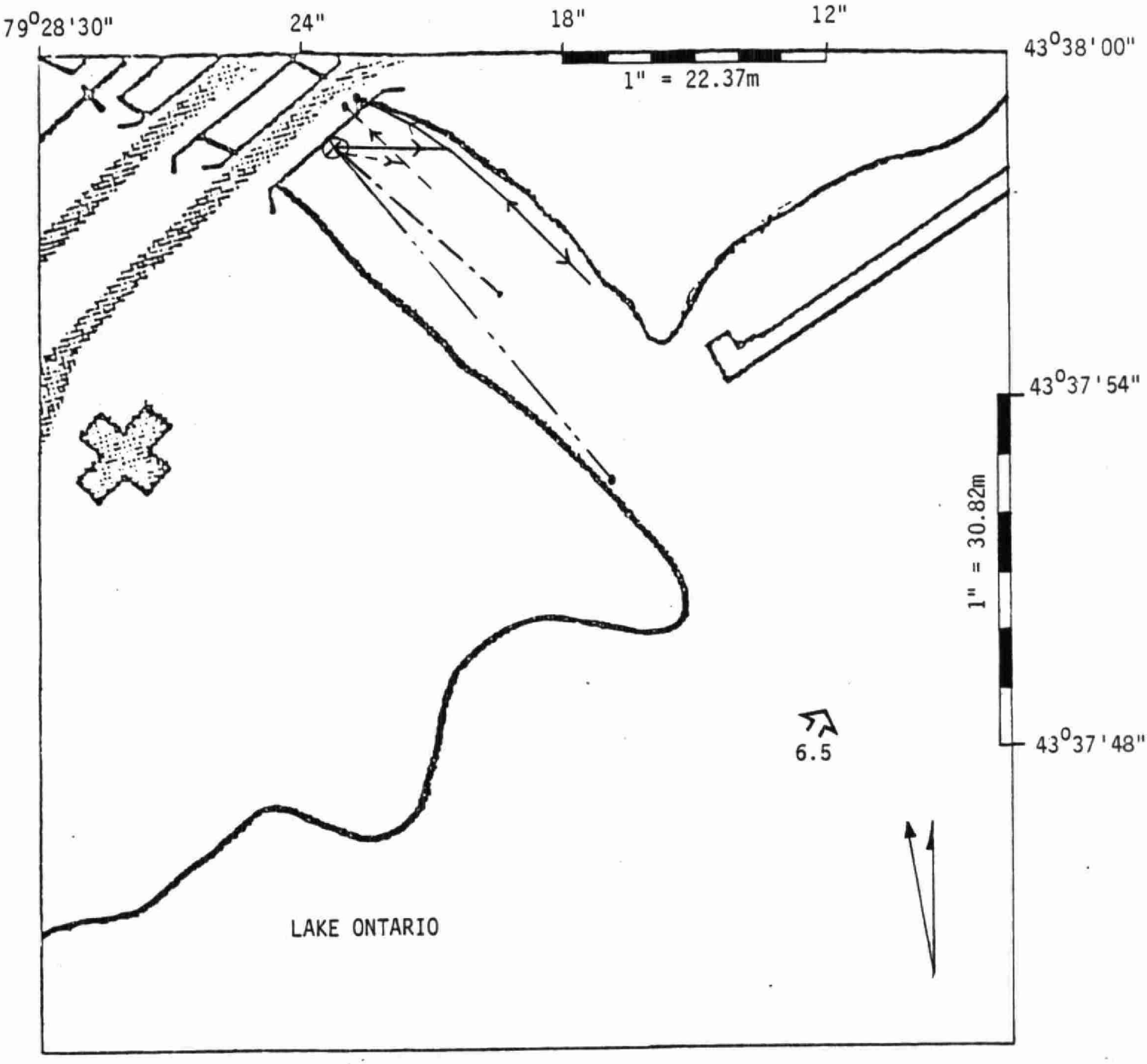


FIGURE 3(b)



OCT. 4/84 - CLUSTER RELEASE AT BRIDGE WIND: SW @ 215° at 6.5-8 km/hr

⊗ Release Point @ 1034

— — — — #3 1405 Hrs. - Beached under Bridge

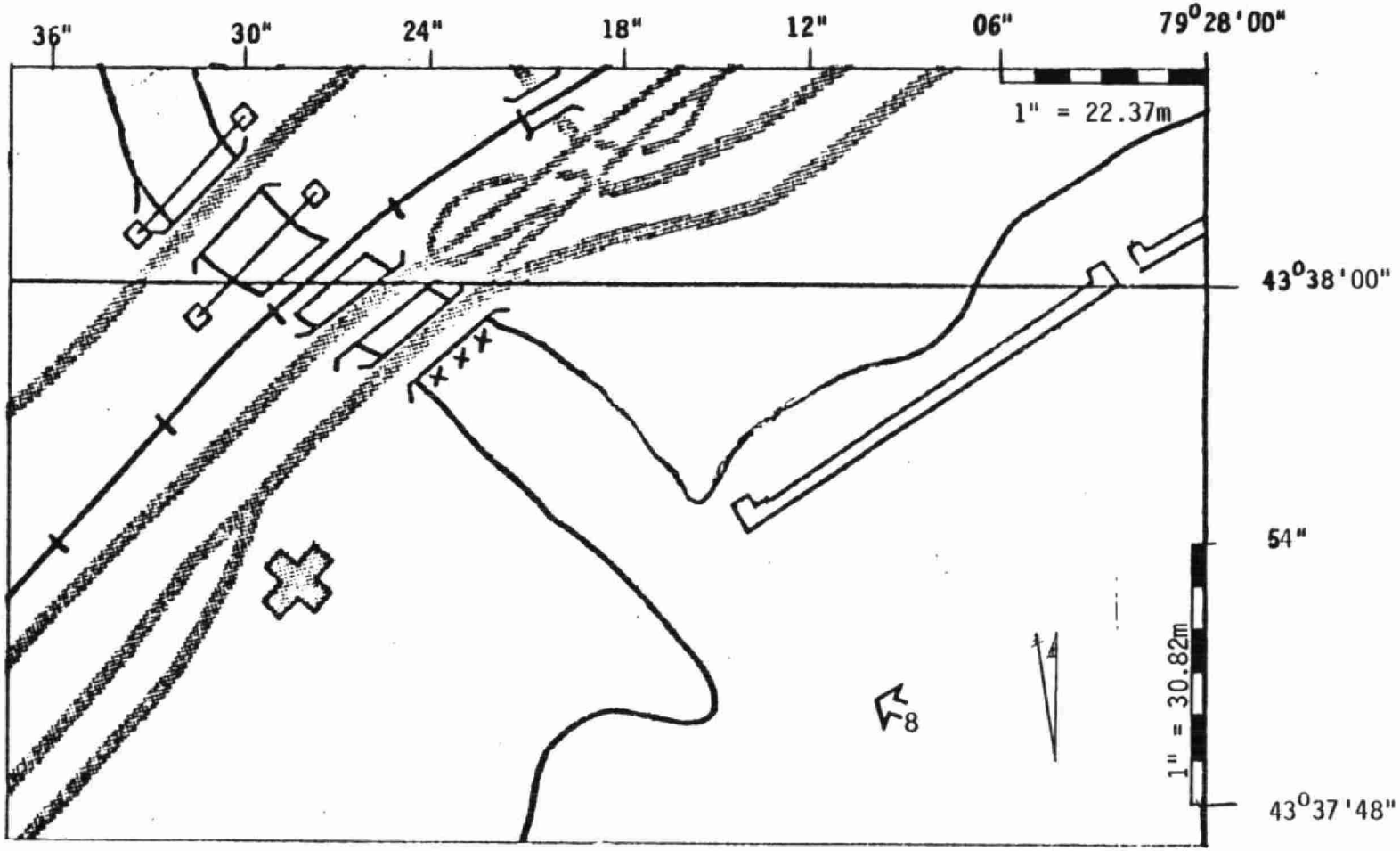
———— #1 1445 Hrs. - Retrieved - Had the highest velocity of all drogues

— - - —— #4 1442 Hrs. - Retrieved

—— - —— #2 1444 Hrs. - Retrieved

NOTE: Due to spurious Loran-C readings not realized until data analysis was begun, this plot indicates only approximate positions of individual drogue tracks.
All drogues moved back and forth within confines of river and at time of retrieval all were moving towards bridge.

Figure 4



SEPT. 11/84 - LINE OF DROGUES - TIME SEQUENTIAL RELEASE

X - Indicates Release Points Across River at Bridge
WIND: SE @ 120° at 8-12 km/hr

Figure 5

HUMBER RIVER OUTFALL - SEQUENTIAL RELEASE @ BRIDGE

Date: September 11 1984
Weather: Overcast with rain, turning partly cloudy by late afternoon.
T = 15°C @ 1000 hours
Wind: 3 - 8 km/h increasing to 8 - 12 km/h @ 120°
Release A: A1 @ 1152; A2 @ 1153; A3 @ 1150

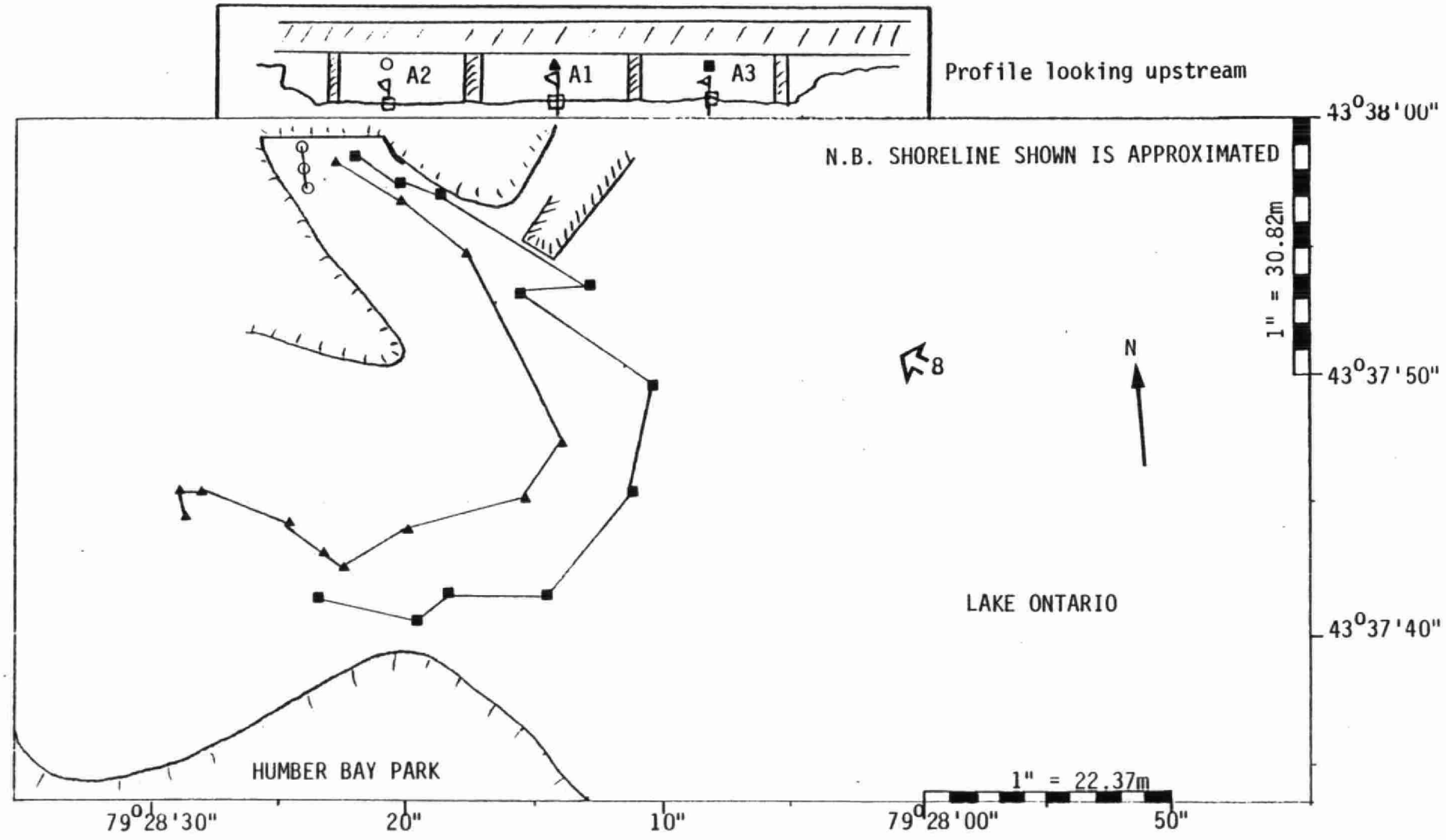


Figure 6

HUMBER RIVER OUTFALL - SEQUENTIAL RELEASE @ BRIDGE

Date: September 11 1984
Weather: Overcast with rain, turning partly cloudy by late afternoon
Wind: 3 - 8 km/h, increasing to 8 - 12 km/h @ 120°
Release B: B1 @ 1250; B2 @ 1251; B3 @ 1249 (as Release A)

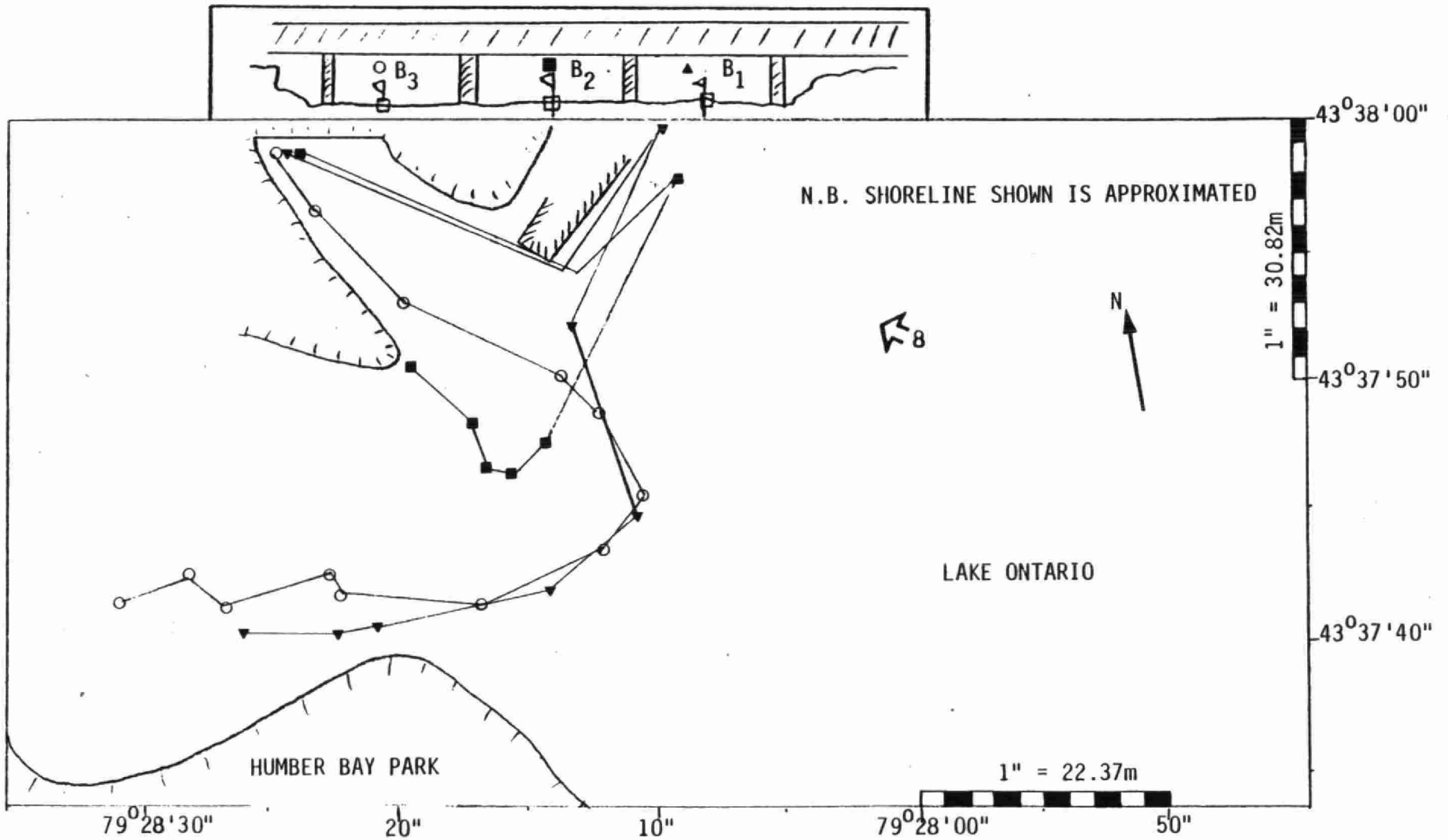


Figure 7

HUMBER RIVER OUTFALL - SEQUENTIAL RELEASE @ BRIDGE

Date: September 11 1984
Weather: Overcast with rain, turning partly cloudy by late afternoon
Wind: 3 - 8 km/h increasing to 8 - 12 km/h a 120°
Release C: C1 @ 1332; C2 @ 1333; C3 @ 1331 (as Release A)

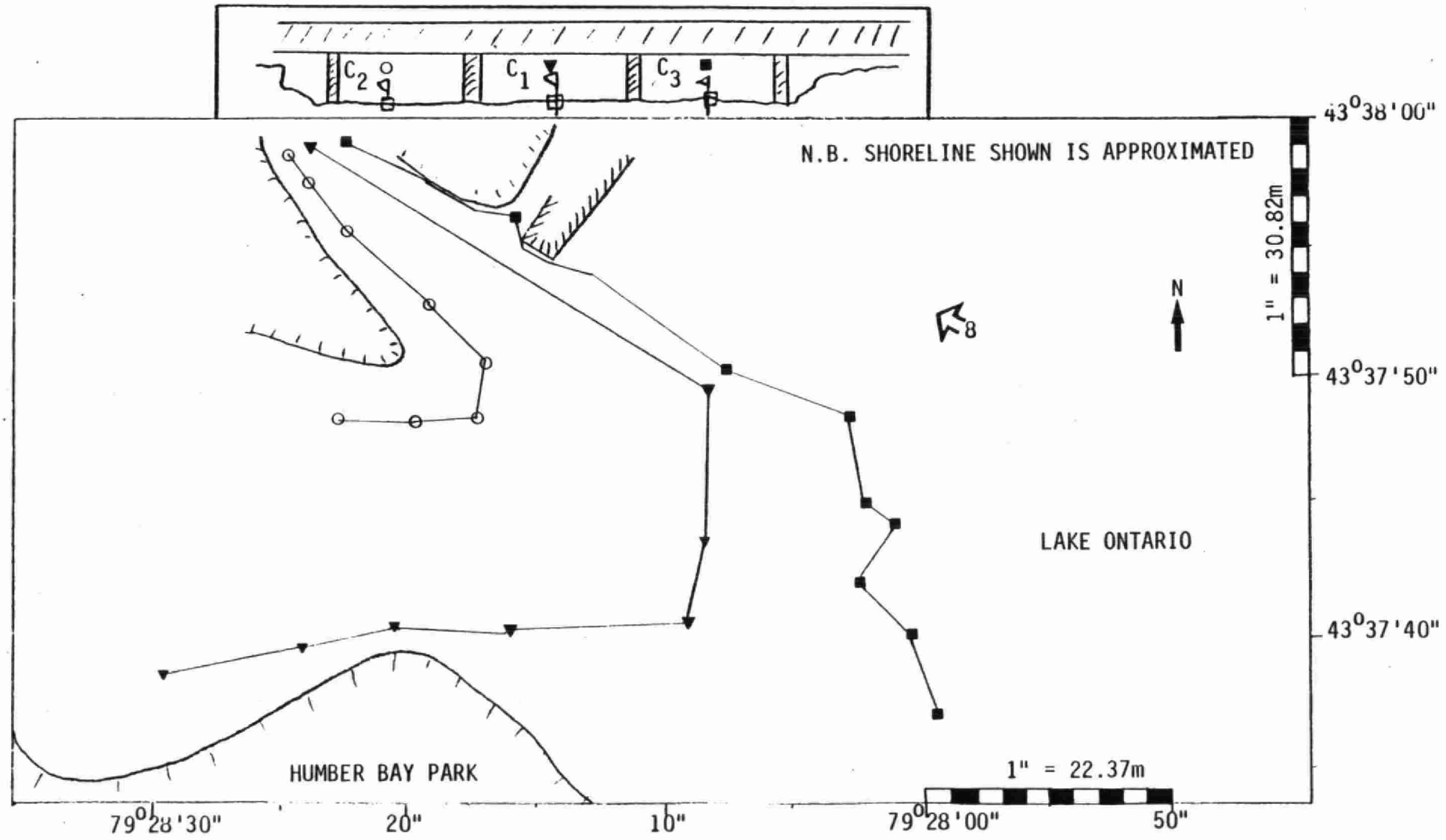


Figure 8

HUMBER RIVER OUTFALL - SEQUENTIAL RELEASE @ BRIDGE

Date: October 9, 1984
Weather: Cloudy with fog
T = 10-12°C @ 1030 hours
Wind: Calm

Release A: A1, A2, A3, A4 @ 1040 hours

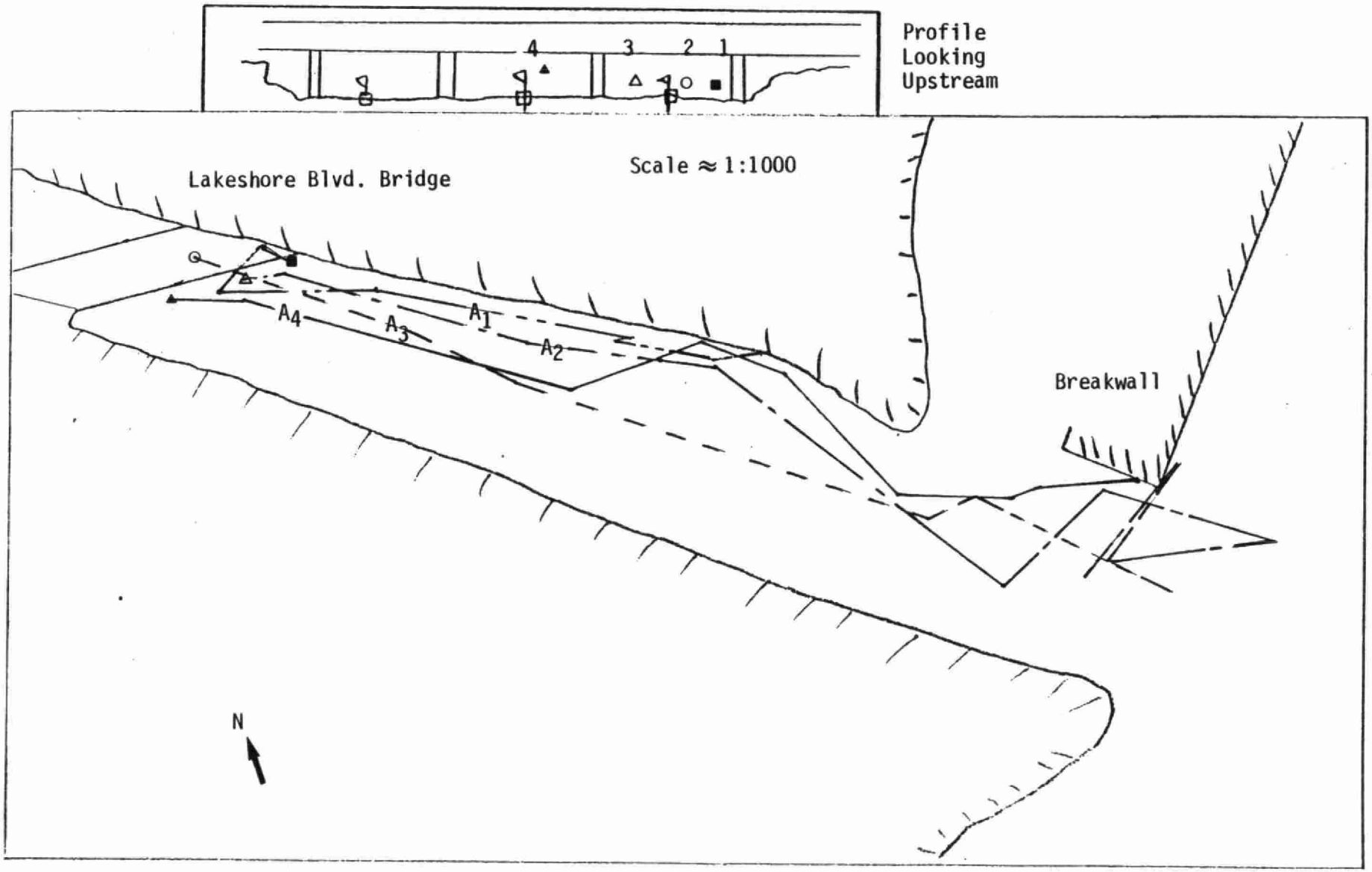


Figure 9

HUMBER RIVER OUTFALL - SEQUENTIAL RELEASE @ BRIDGE

Date: October 9, 1984
Weather: Cloudy with fog
T = 10-12 °C @ 1030 hours
Wind: Calm

Release B: B1, B2, B3, B4 @ 1115 hours

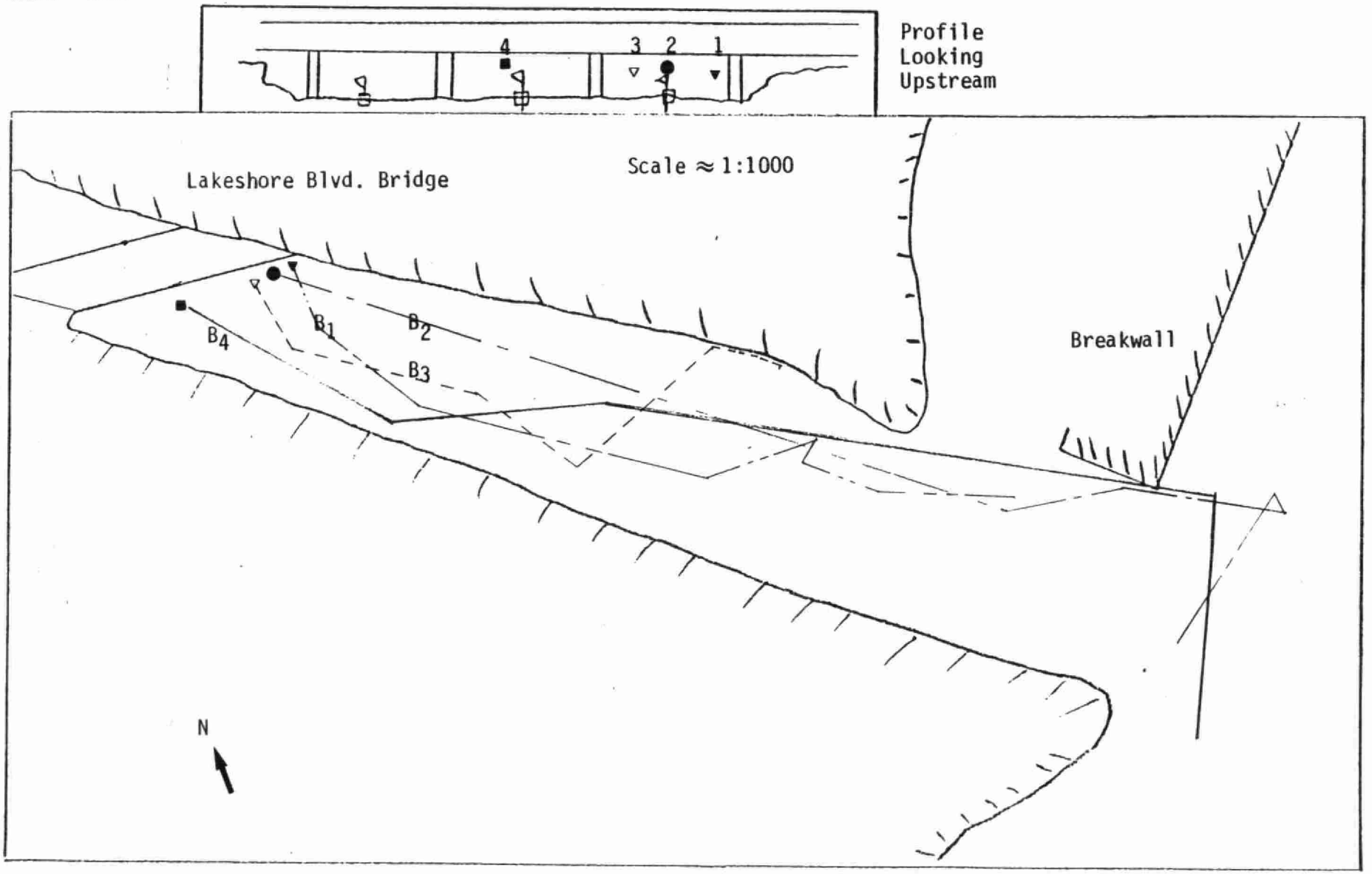


Figure 10

HUMBER RIVER OUTFALL - SEQUENTIAL RELEASE @ BRIDGE

Date: October 9, 1984
Weather: Cloudy with fog
T = 10-12°C @ 1030 hours
Wind: Calm

Release C: C1, C2, C3, C4 @ 1150 hours

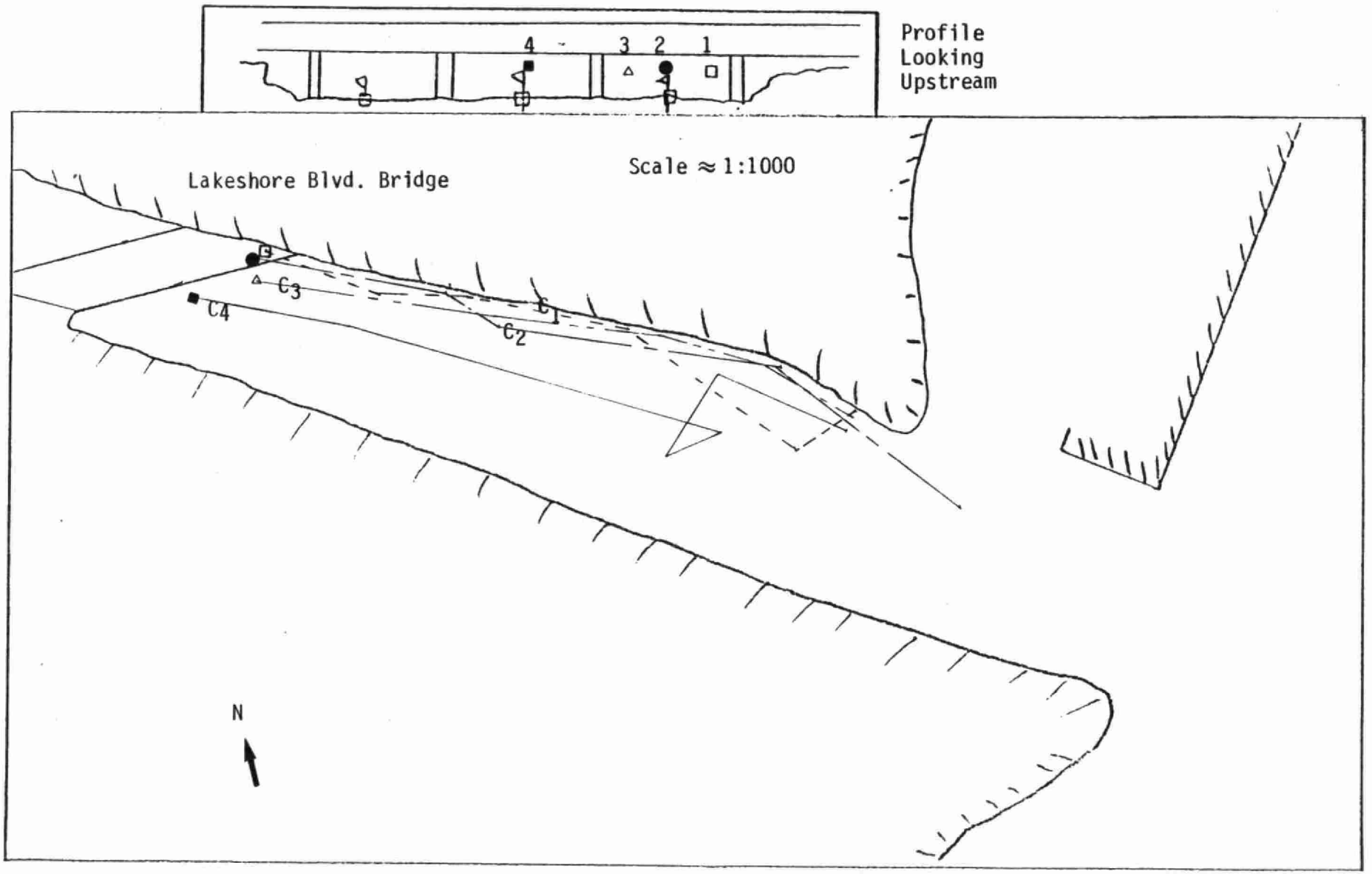


Figure 11

STUDY AREA FOR EXCHANGE STUDIES CARRIED OUT ON AUGUST 14 and 27, 1984

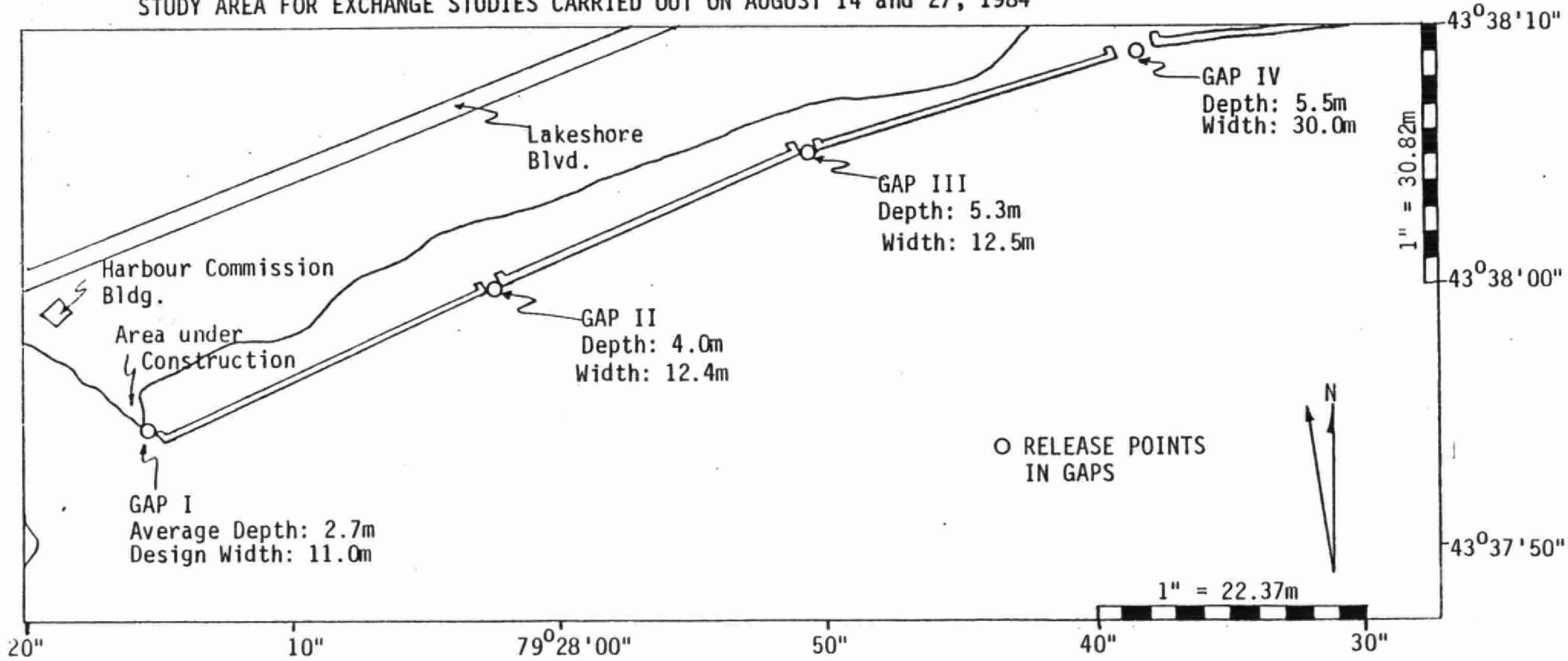


Figure 12

HUMBER RIVER - EXCHANGE GAP I

Sail Drogue @ 1.0 m depth

August 14 1984

Wind: SW gusting to 14 km/h
Waves: 0.15 m
Average Depth of Gap: 2.7 m

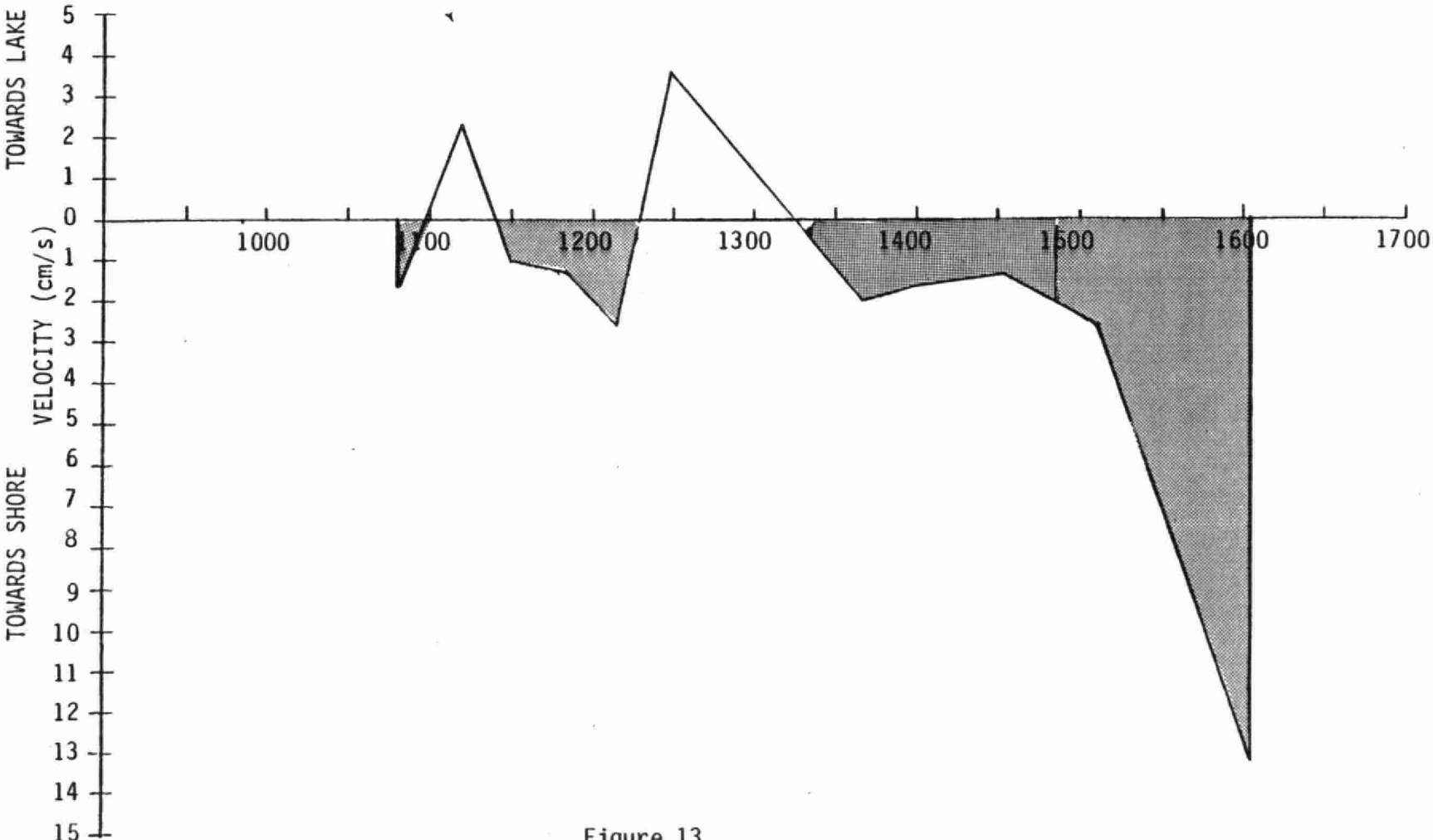


Figure 13

HUMBER RIVER - EXCHANGE GAP II

Sail Drogue @ 1.0 m depth
August 14 1984

Wind: SW gusting to 14 km/h
Waves: 0.15 m
Average Depth of Gap: 4.0 m

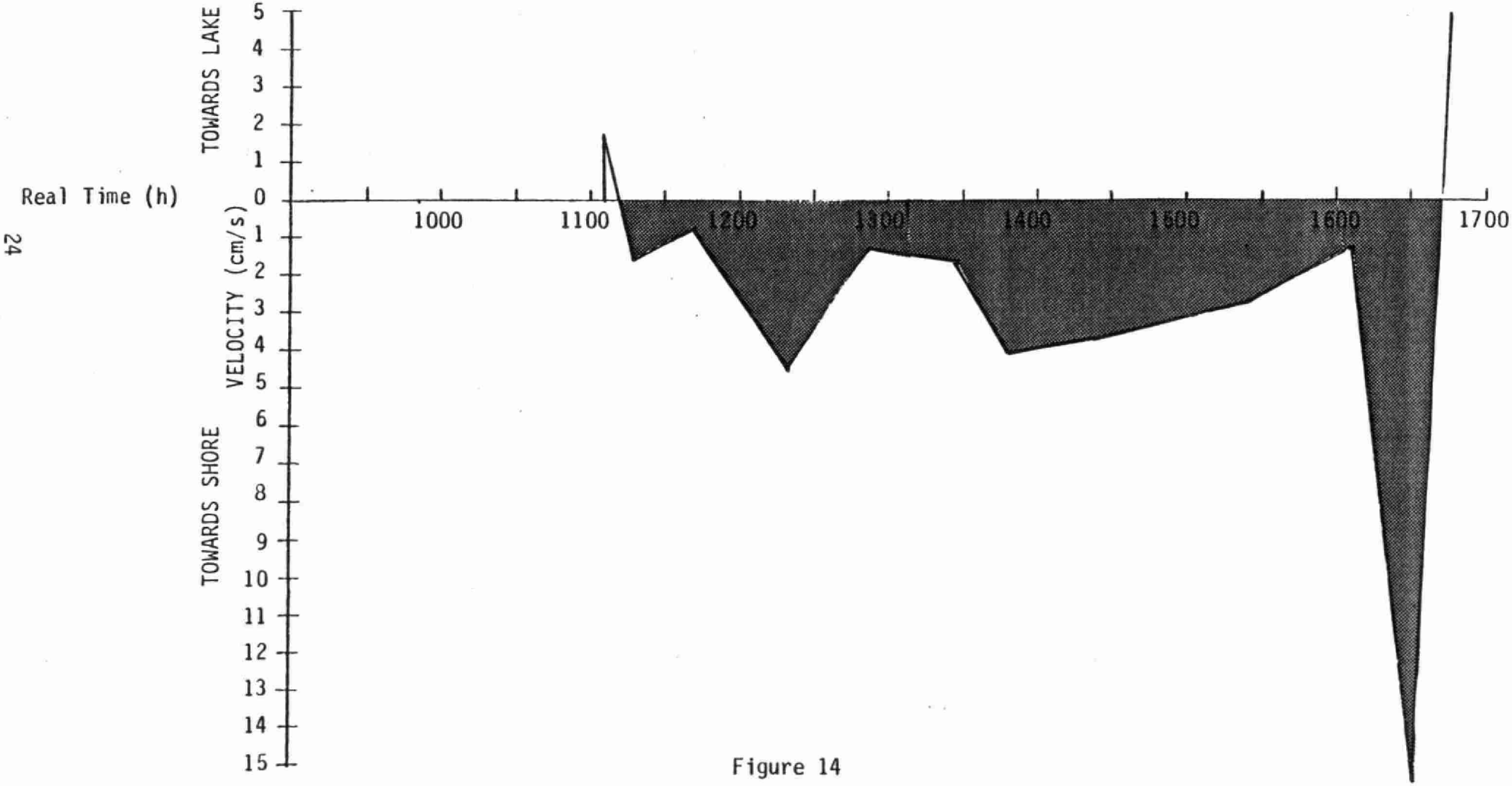


Figure 14

HUMBER RIVER - EXCHANGE GAP III

Sail Drogue @ 1.0 m depth

August 14 1984

Wind: SW gusting to 14 km/h
Waves: 0.15 m
Average Depth of Gap: 5.3 m

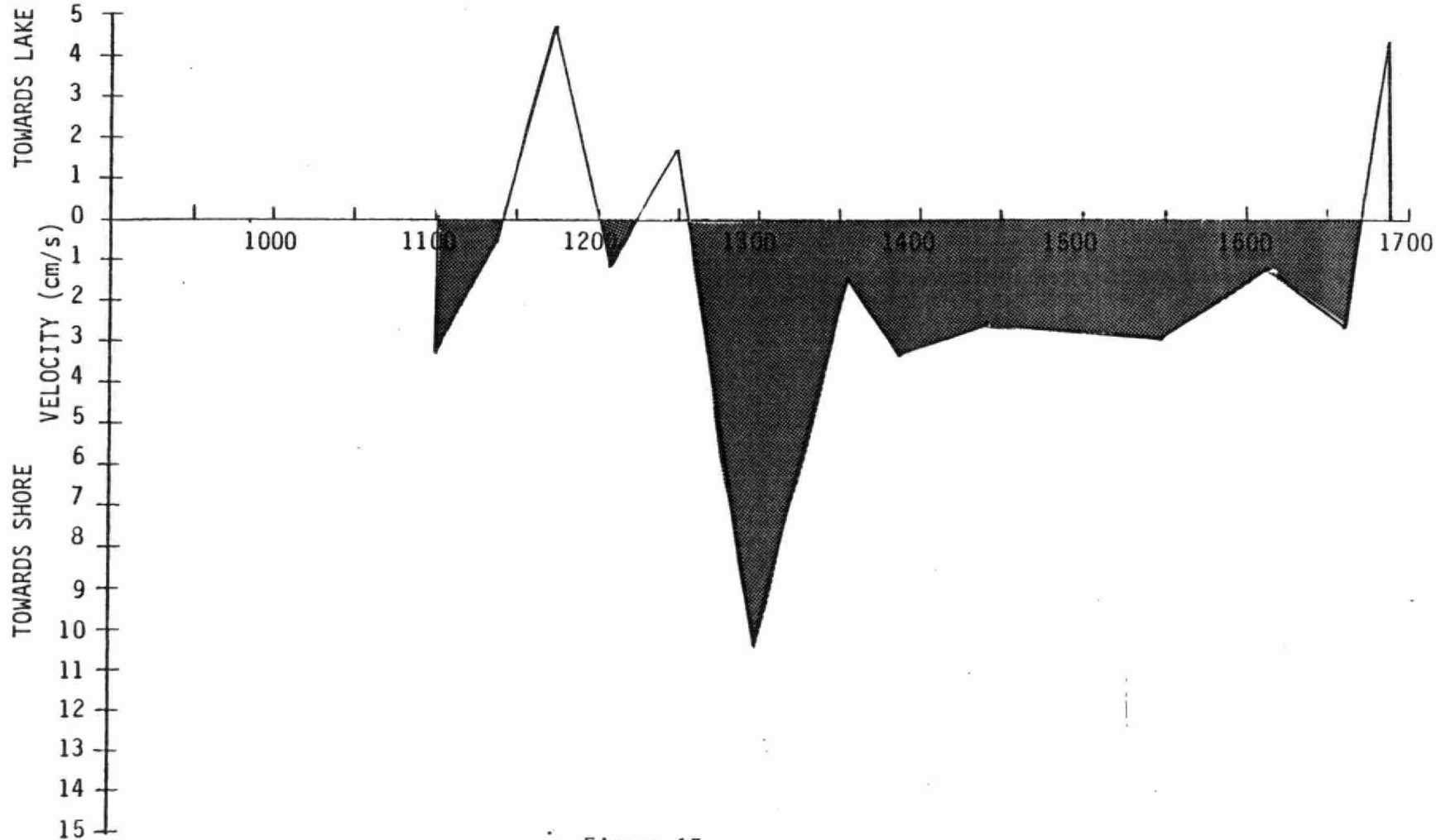


Figure 15

HUMBER RIVER - EXCHANGE GAP IV

Sail Drogue @ 1.0 m depth

August 14 1984

Wind: SW gusting to 14 km/h
Waves: 0.15 m
Average Depth of Gap: 5.5 m

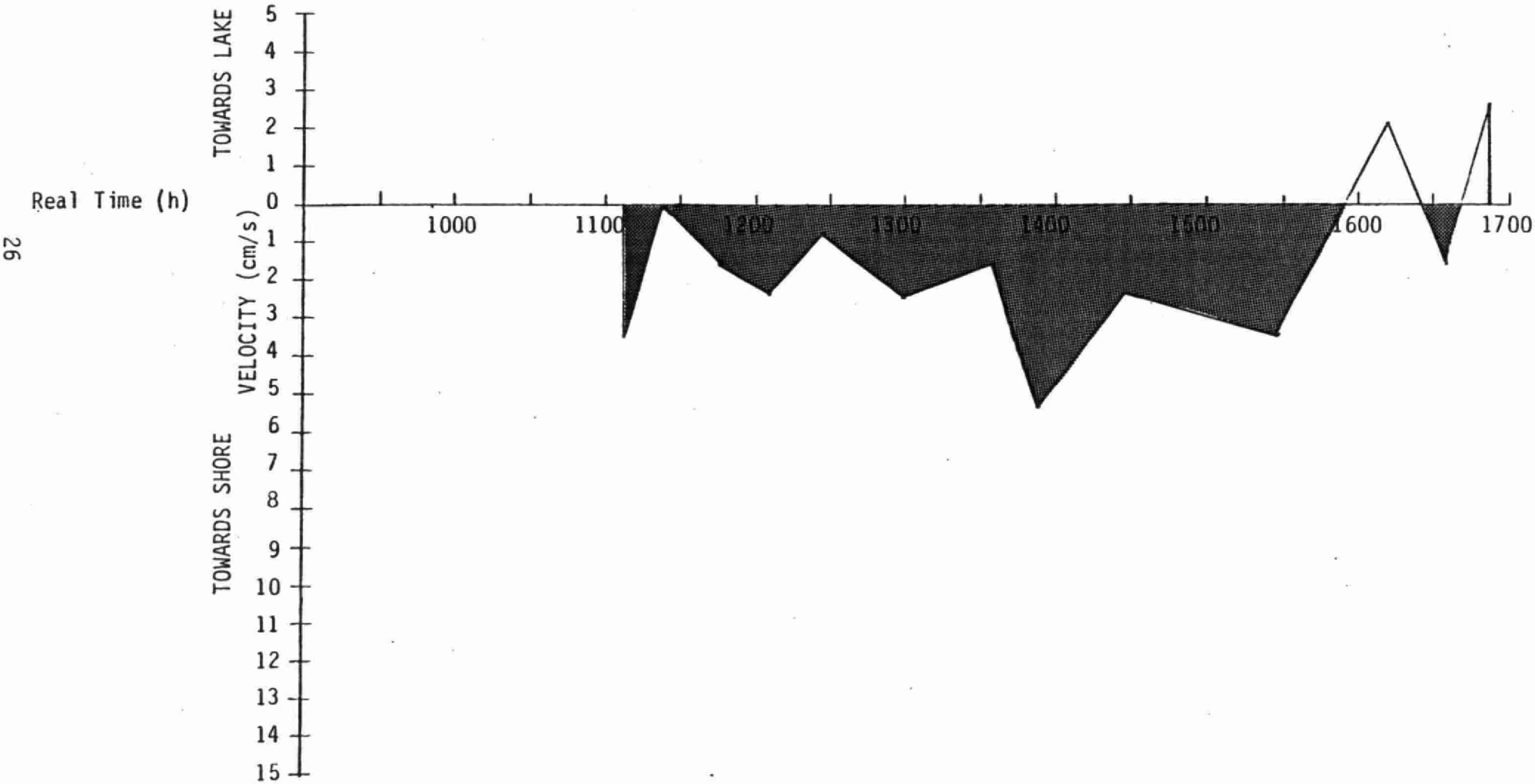


Figure 16

HUMBER RIVER - EXCHANGE GAP I (WESTERN GAP)

Sail Drogue @ 1.0 m depth

August 27 1984

Wind: SW 8 - 13 km/h
Waves: 0.5 - 0.8 m

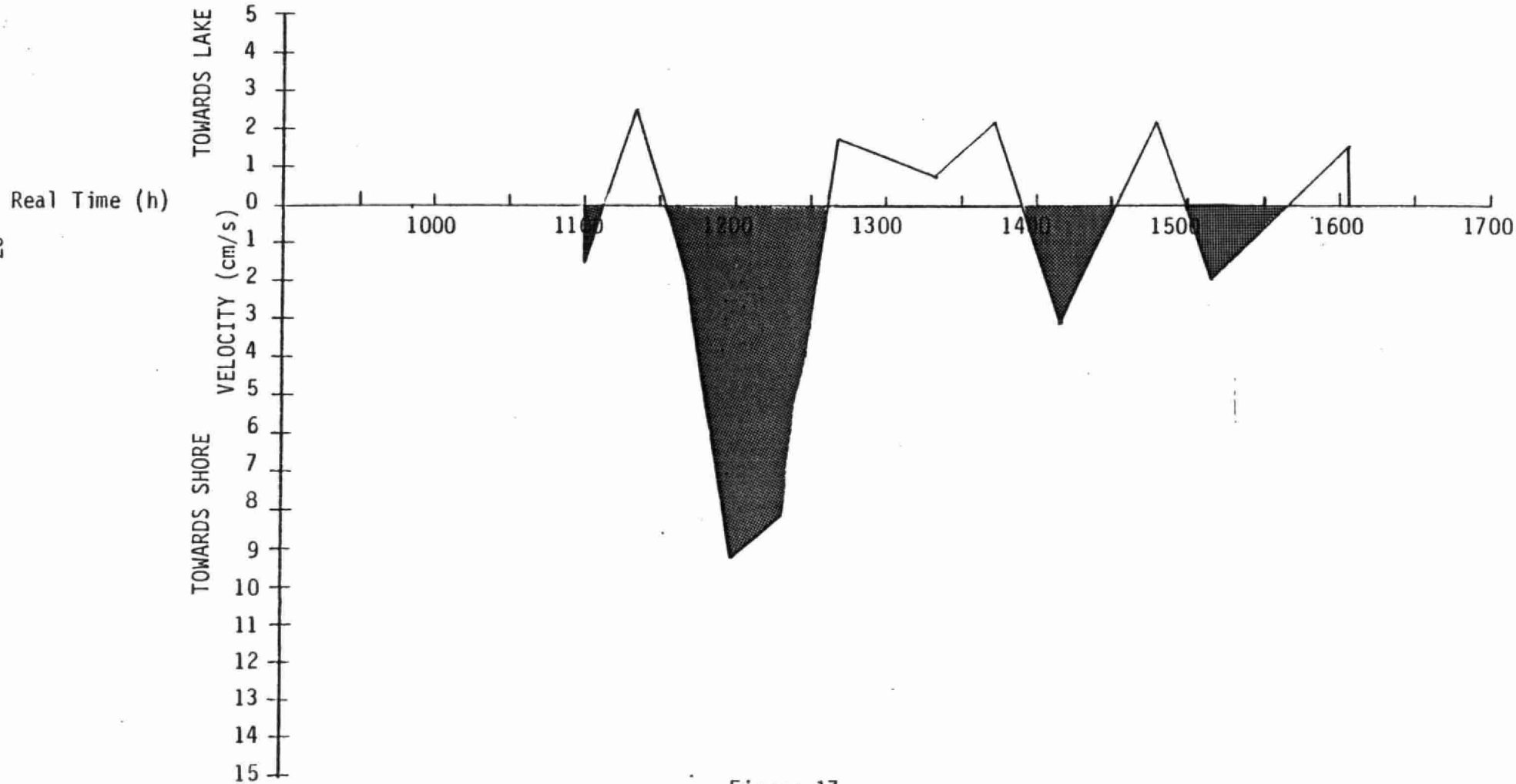


Figure 17

HUMBER RIVER - EXCHANGE GAP II

Sail Drogue @ 1.0 m depth

August 27 1984

Wind: SW 8 - 13 km/h
Waves: 0.5 - 0.8 m

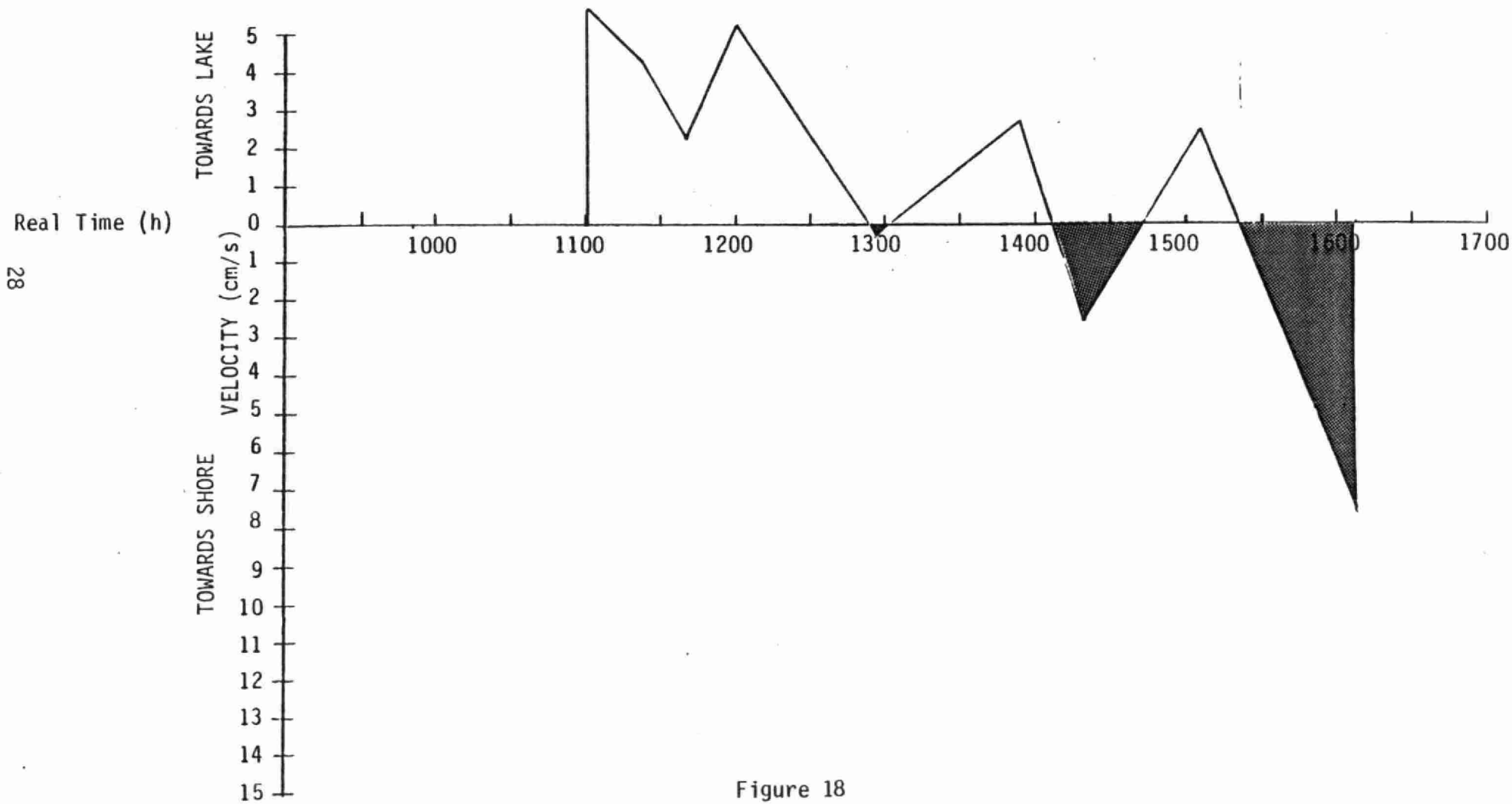


Figure 18

HUMBER RIVER - EXCHANGE GAP III

Sail Drogue @ 1.0 m depth

August 27 1984

Wind: SW 8 - 13 km/h
Waves: 0.5 - 0.8 m

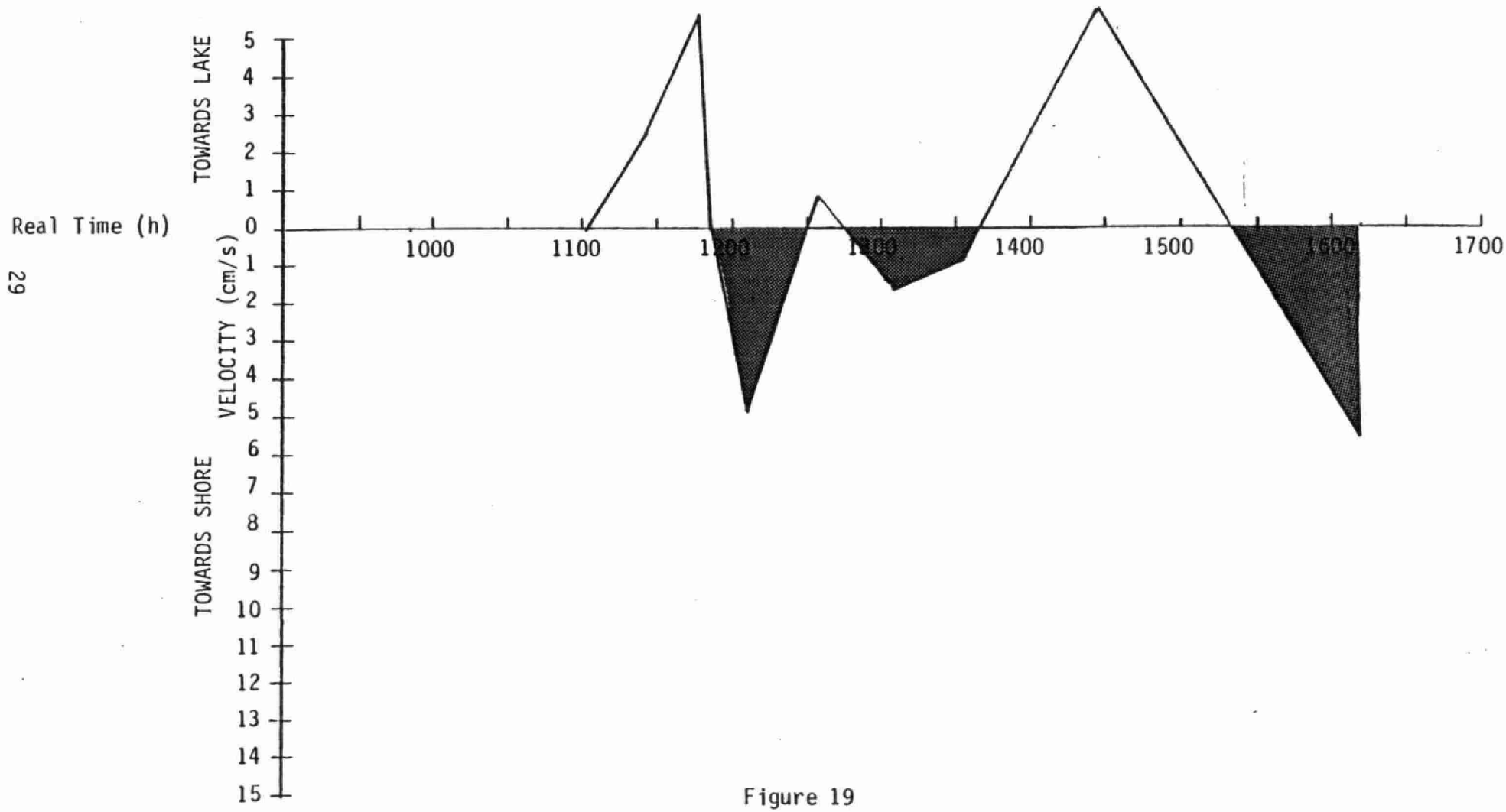


Figure 19

HUMBER RIVER - EXCHANGE GAP IV

Sail Drogue @ 1.0 m depth

August 27 1984

Wind: SW 8 - 13 km/h
Waves: 0.5 - 0.8 m

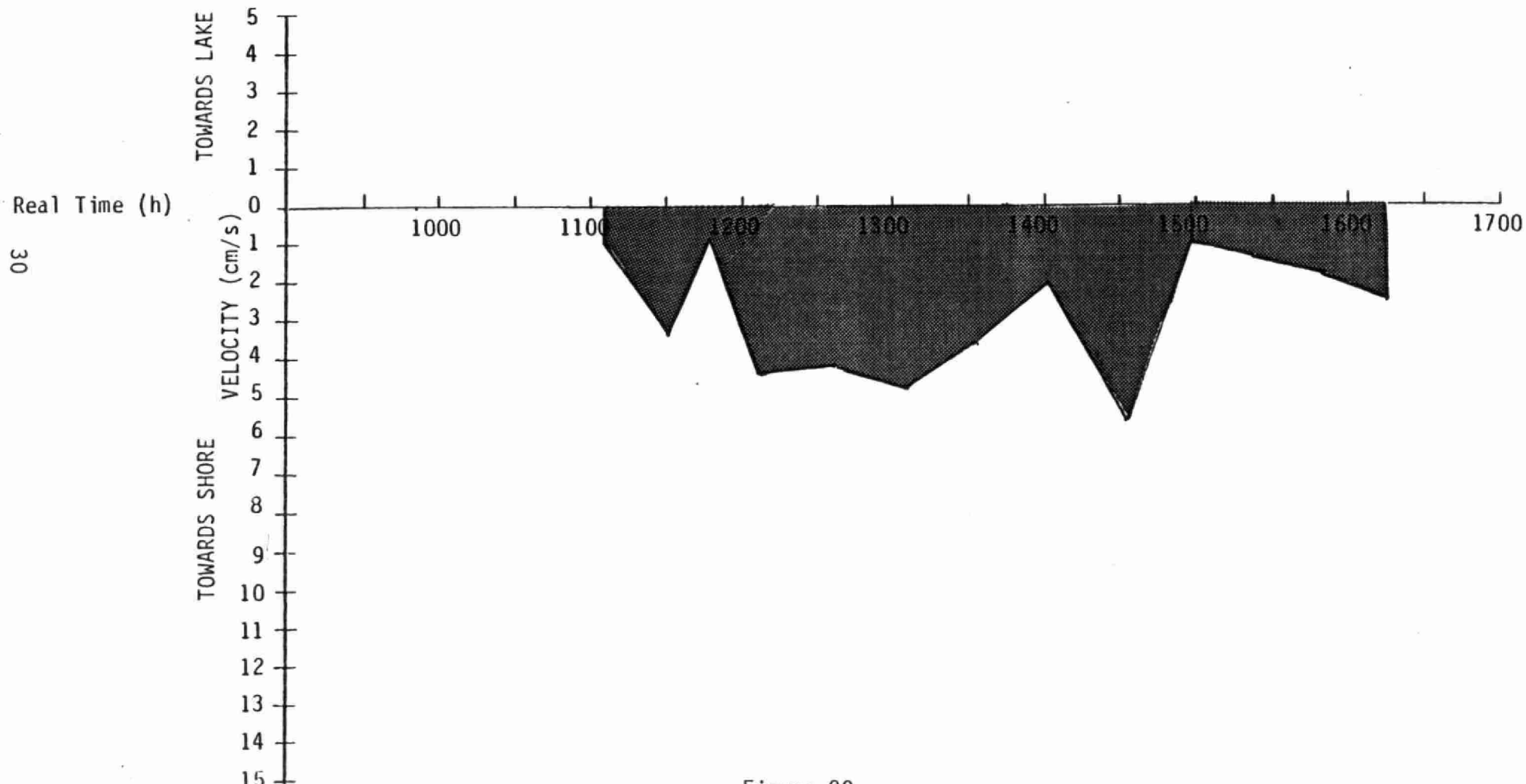
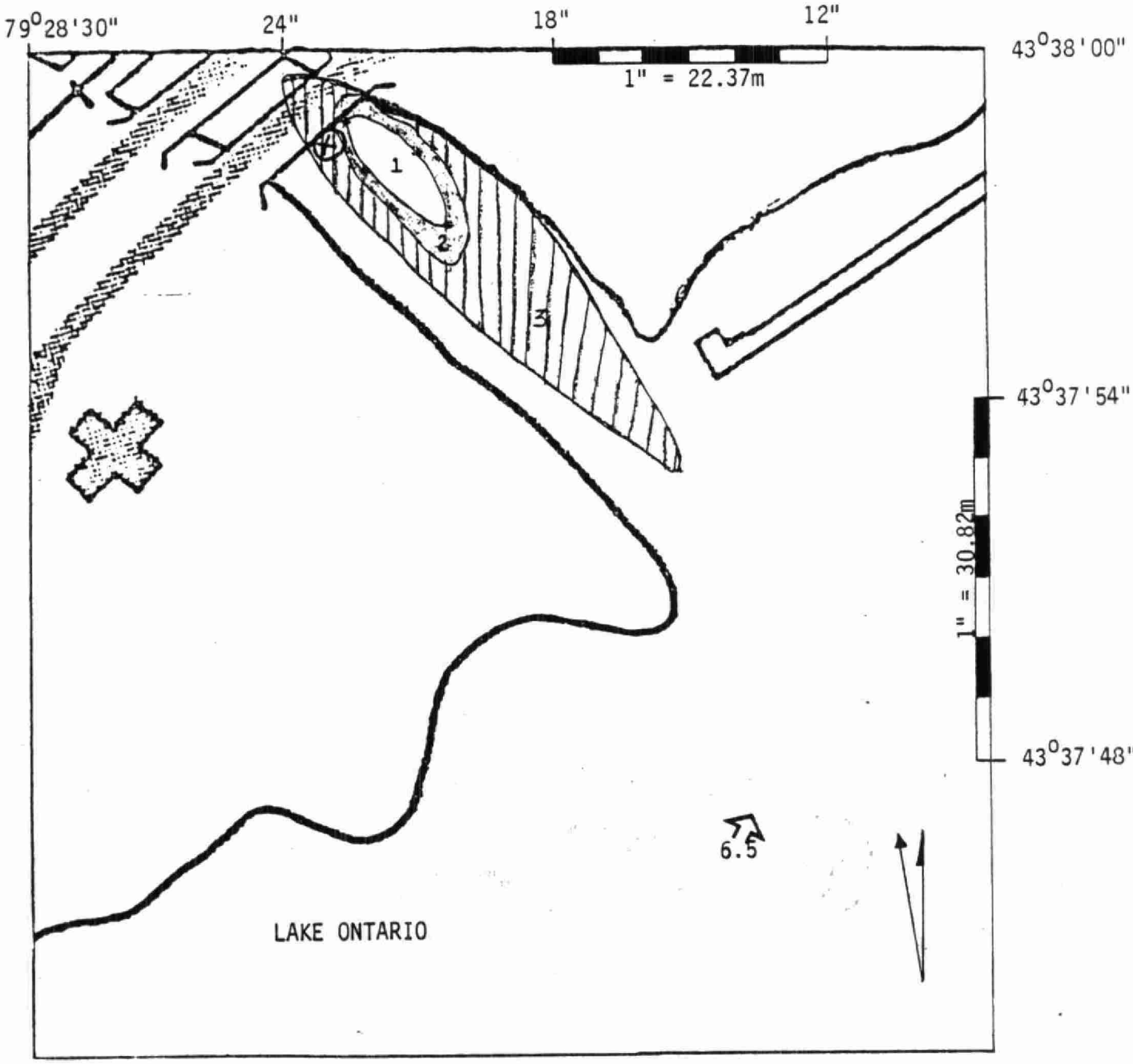


Figure 20



OCT. 4/84 - DYE RELEASE AT BRIDGE

⊗ Release Point @ 1050
Average Time of Run #1 - 1113:45
" " " #2 - 1201:45
" " " #3 - 1323:30

WIND: SW @ 215° at 6.5 - 8 km/hr

Figure 21

	DATE DUE		